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GEOINFORMATION SYSTEM OF GEOMAGNETIC PSEUDOSTORM PARAMETERS REGISTRATION AND ANALYSIS

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Abstract. A new approach to the development of geoinformation systems for geomagnetic pseudostorm parameters registration is supposed. The term "geomagnetic pseudostorm" supposes an influence of geomagnetic field to the object in its existence area within anisotropic geomagnetic field in condition of non-zero object speed. The paper describes the results of experiment, which demonstrates geomagnetic pseudostorm effect on example of civil airplane, performing an air route AA937 (American Airlines).

Key words: geoinformation systems; geomagnetic field; geomagnetic pseudostorm.

1. INTRODUCTION

In modern world specialists in biology, medicine, geophysics, geology, technics, sociology, psychology and many other spheres pay great attention to the analyses of external geomagnetic variations (GMV). It is necessary to compare GMV parameters with their influence on existence and progress of objects and systems of various origin types.

This interest is based on idea, that according to statistic data some GMV components or their combinations can directly or indirectly affect on biological, technical, geological and other objects and systems in whole or on a human in part. As a result distorted normal conditions of the system existence necessitate it either to adapt to magnetic state changes (through deformation, mutation, etc.) or to keep existing there in stress (unstable) mode [1].

The problem of negative GMV influence is especially acute in the sphere of development and maintenance of various airspace equipment. This situation is mainly caused by human interaction with a great number of complicated navigation, information measuring and controlling systems in conditions of flight incessancy and significant distances from terrestrial technical services.

The statistics of emergency situations onboard defines, that the great majority of them are connected with human factor (57%) and/or board equipment failure (22%). Let's compare this fact with mainly negative, unpredictable and little studied GMV influence on both technical and biological systems and objects [2–6]. It is supposed, that detailed GMV analyses (including geomagnetic pseudostorm), and synthesis of algorithms of their minimizations can facilitate increasing board equipment resiliency and flight safety.

So, the research, which is described in this paper, has a task of detecting the amplitude-frequency range of geomagnetic pseudostorm effect, its analyses, comparison with the analogical natural kind GMV parameters and making conclusions about minimizing geomagnetic pseudostorm effect on aircraft flight.

2. CONTEMPORARY RESEARCH OF GEOMAGNETIC FIELD AND ITS VARIATIONS

Nowadays a problem of GMV parameters research and analyses is partly solved by a number of magnetic observatories, which are mainly based on Europe territory.

Published research materials mainly include the results on amplitude range, character and dynamics of geomagnetic field parameters in the Earth point with appropriate geographical coordinates (latitude, longitude, altitude). But it is still unclear, how much is the value of particular GMV influence on object of both biological and technogenic type is. These particular GMV take place only to the appropriate object within the concrete space limits of its existence, when the object is moving in conditions of geomagnetic field anisotropy.

In scientific papers [7–8] the term of geomagnetic pseudostorm effect is defined. According to this, the geomagnetic pseudostorm effect is a geomagnetic field force action to the object (including biological type objects) in objects existence area

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within undisturbed anisotropic geomagnetic field in conditions of none-zero angular and / or linear velocity of the object.

Thereby this paper represents the primary scientific problem of detection, analyses and estimation of main parameters of particular GMV, which take place in conditions of undisturbed geomagnetic field during the aircraft flight.

3. CONCEPTION OF GEOMAGNETIC PSEUDOSTORM

To demonstrate the example of geomagnetic pseudostorm effect let's compare magnetic influence of disturbed geomagnetic field to some stationary object with force action to the same object in conditions of anisotropic liquid flow, which permanently changes its direction and velocity. This analogy demonstrates dynamics of performed magnetic-force actions from the real magnetic storms to the studied static object or system.

Then, saving liquid anisotropic properties, let's qualitatively estimate force actions to the same object in static area with none-zero angle and linear velocity. It is obvious, that the common dynamics in modified conditions can be compared with dynamics from the mentioned example. It depends on both object velocity and gradient of area heterogeneity. To formalize this kind of influence let's project this analogy to object or system in anisotropic magnetic field. It is supposed to enter the term geomagnetic pseudostorm (GPS), which demonstrates real magnetic storms special influence on object in conditions of undisturbed geomagnetic field anisotropy and none-linear velocity of this object.

4. MODELING AND ESTIMATION OF UNDISTURBED GEOMAGNETIC FIELD PARAMETERS

Let's define the full vector of Earth magnetic field induction in geographic point with geospatial coordinates (latitude, longitude, altitude, year) as a following sum:

$$\boldsymbol{B}_{ge} = \boldsymbol{B}_1 + \boldsymbol{B}_2 + \boldsymbol{B}_3,$$

where $\boldsymbol{B}_1$ is a vector of Earth internal sources geomagnetic field induction; $\boldsymbol{B}_2$ is a regular component of the vector of magnetosphere currents geomagnetic field induction, which is calculated in solar-magnetospheric coordinates; $\boldsymbol{B}_3$ is irrational component of the vector of magnetosphere currents geomagnetic field induction.

Magnetic field of Earth internal sources $\boldsymbol{B}_1$ defines force characteristics of undisturbed geomagnetic field made by the electric currents in earth's core (main field), which is ~ 98 % of the whole field. The fields of terrestrial magnetism are made by magnetic properties of rocks and are about 2 % of the whole field. Besides the field of Earth core decreases quicker than the main field. And at altitude about 100 km this value can be ignored.

Let's define the model of main field as a series of spherical harmonics depending on geographic coordinates. It is known, that this approach with series size of 10–13 harmonics provides a calculation error of main geomagnetic field about 2 %.

In this case scalar potential of Earth internal sources geomagnetic dipole induction U [nT×km] in the point with spherical coordinates r, θ, λ is defined as follows:

$$U = R_E \times$$
$$\times \sum_{n=1}^{N}\sum_{m=0}^{n}\left(g_n^m \cos(m\lambda) + h_n^m \sin(m\lambda)\right)\left(\frac{R_з}{r}\right)^{n+1} P_n^m \cos(\theta), \quad (1)$$

where r is the distance from Earth center to observation point (geocentric distance), [km]; λ is a longitude from the Greenwich meridian, [degrees]; θ is a polar angle (addition to latitude, θ = (π/2)–φ', [degrees], where φ' is latitude in spherical coordinates, [degrees]); R_E = 6371.03 is an average radius of Earth, [km]; $g_n^m(t)$, $h_n^m(t)$ are spherical harmonic coefficients [nTesla], which depend on time parameter; P_n^m are Schmidt-normalized associated Legendre functions with power n and order m [7–8].

In specialized literature an expression (1) is known as Gaussian series. This expression is defined as international standard of undisturbed state of Earth magnetosphere. So it is possible to assume, that $\boldsymbol{B}_0 \approx \boldsymbol{B}_1$, where $\boldsymbol{B}_0$ is an induction of undisturbed geomagnetic field in the local point of Earth surface. Schmidt-normalized associated Legendre function P_n^m from expression (1) can be defined as orthogonal polynomial:

$$P_n^m(\cos(\theta)) = 1\cdot 3\cdot 5 ... \sqrt{\frac{\varepsilon_m}{(n+m)!(n-m)!}} \times$$
$$\times \sin^m\theta[\cos^{n-m}\theta - \frac{(n-m)(n-m-1)}{2(2n-1)}\cos^{n-m-2} +$$
$$+\frac{(n-m)(n-m-1)(n-m-2)(n-m-3)}{2\cdot 4(2n-1)(2n-3)}\cos^{n-m-4}\theta - ...],$$

where ε_m is normalization factor (ε_m = 2 for $m \geq 1$ and ε_m = 1 for m = 0); n and m are power and order of spherical harmonics.

5. EXPERIMENT AND ITS RESULTS ANALYSES

Let's consider the example of flight *AA*937 New York – Rio de Janeiro of the American Airlines airplane *Boeing* 767. An approximate plane path is represented on Fig. 1.

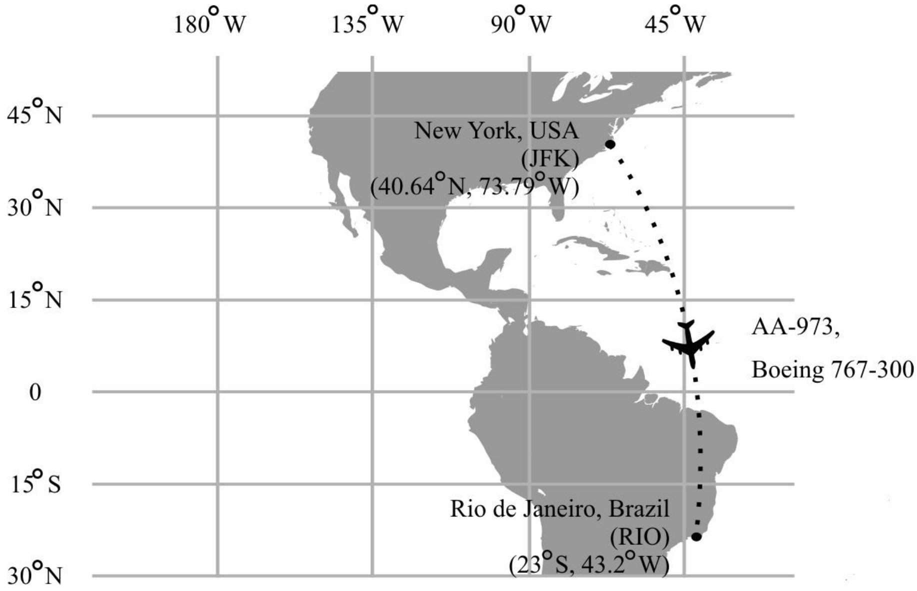

Fig. 1. An approximate plane path of *Boeing* 767-300 on flight *AA*973

Table 1

Experimental data

#	Latitude	Longitude	Altitude m./ft.	B_X, nTesla	B_Y, nTesla	B_Z, nTesla	B, nTesla
1.	40.63° N	73.77° W	2/6	23781	-4665	47771	53566
2.	39.22° N	72.39° W	4633/15200	24211	-4940	46275	52459
3.	37.71° N	70.96° W	10698/35100	24619	-5206	44594	51204
4.	35.86° N	69.18° W	11033/36200	25147	-5543	42598	49776
5.	32.61° N	66.52° W	11033/36200	25978	-6011	39032	47270
6.	28.60° N	63.53° W	11033/36200	26821	-6497	34471	44157
7.	25.95° N	61.71° W	11033/36200	27289	-6787	31405	42154
8.	22.97° N	59.82° W	11033/36200	27741	-7102	27937	40006
9.	19.86° N	58.04° W	11033/36000	28123	-7426	24316	37912
10.	14.49° N	55.29° W	11033/36000	28473	-7992	18023	34633
11.	10.41° N	53.45° W	11033/36000	28346	-8393	13222	32384
12.	06.44° N	51.67° W	11033/36000	27782	-8729	8507	30338
13.	01.75° N	49.91° W	11033/36000	26483	-8945	3202	28136
14.	05.93° S	47.43° W	11033/36000	23134	-8809	-4437	25149
15.	14.32° S	45.14° W	11033/36000	18806	-8031	-10569	23019
16.	20.91° S	43.71° W	5974/19600	15673	-7175	-13762	22057

The Table 1 represents the results of experiment and describes magnetic field variations onboard *Boeing* 767-300 plane on flight *AA*-973. The results are obtained via authors-made program and instrumental complex [9–10]. All the data are registered every 9 minutes (540 seconds).

Figure 2 represents graphical view of exprerimental data of geomagnetic pseudostorm dynamics (Fig 2, a) and the results of frequency analyses (Fig. 2, b). There are some special points: *t*1–*t*2 is the climb time; *t*2–*t*4 is flight time at cruising speed; *t*4–*t*5 is landing time; *t*3 is a moment of passing equator.

Let’s analyze Fig. 2 and compare amplitude-frequency characteristics of geomagnetic pseudo-storm and traditional GMV parameters. The conclusion is that geomagnetic pseudostorm effect amplitude and frequency are bigger than GMV more than 2 orders.

It is obvious that geomagnetic pseudostorm parameters depend on both region of aircraft flight and its performance characteristics (Table 2).

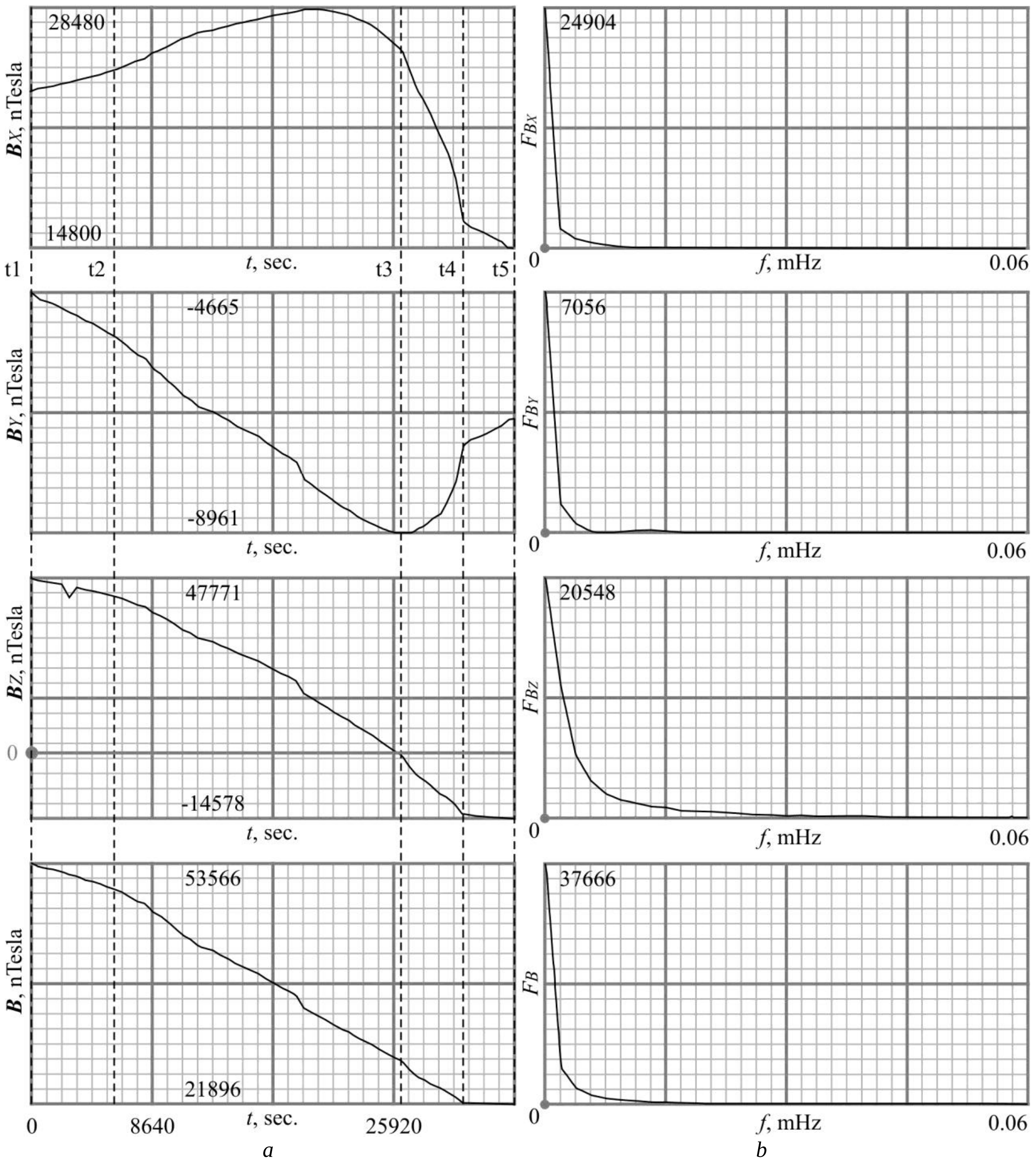

Fig. 2. Results of amplitude-frequency analyses of geomagnetic pseudostorm effect

Table 2

Performance characteristics of aircrafts

Aircraft Type	Practical upper level, km	Cruising speed, km/h	Maximum speed, km/h
Il-96	12000	870	910
Boeing 767-300	12800	870	910
A 350-800	13100	903	945
F-15	20000	917	2650
Mig-31	20600	2500	3000
X-43A	30000	–	11230

So it is detected that amplitude–frequency range of geomagnetic pseudostorms is limited with 0–70000 nTesla by amplitude and with 0–3 mHz by frequency. That is at least three times bigger than traditional GMV.

Let's consider metal (Duralumin) fuselage of aircraft in variable magnetic field. According to Maxwell's principles [12] there is electromagnetic field of appropriate frequency and amplitude on board of aircraft. This field is initiated by geomagnetic pseudostorm effect.

6. CONCLUSION

On the basis of researched results it is possible to make conclusion that geomagnetic pseudostorms take place during aircraft flights. Their amplitude and frequency are much bigger than natural GMV amplitude-frequency parameters.

So it is assumed to extend traditional ranking of electromagnetic waves by the International Telecommunication Union (ITU) to the 0–3 Hz range, which is supposed to be named as "sub extremely low frequency range" (SELF).

However the problem of neutralization (screening) of negative geomagnetic pseudostorm influence to biological and technical objects and systems onboard of aircraft is still unsolved and insufficiently explored. It challenges a lot of new technical and scientific problems for modern industry.

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МЕТАДАННЫЕ

Название: Геоинформационная система расчета и регистрации параметров геомагнитной псевдобури.

Авторы: А. Воробьев, Г. Шакирова.

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Аннотация: Предлагается новый подход к регистрации и расчету параметров геомагнитной псевдобури. Термин «геомагнитная псевдобуря» рассматривается как воздействие геомагнитного поля на объект в условиях его существования в анизотропном магнитном поле при условии его перемещения с ненулевой скоростью. Описаны результаты эксперимента, демонстрирующего эффект геомагнитной псевдобури на примере гражданского самолета, совершающего перелет по маршруту AA937 (American Airlines).

Ключевые слова: геоинформационная система; геомагнитная буря; геомагнитные псевдобури.

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